



**The United States Patent and Trademark Office
On Appeal From The Examiner To The Board
of Patent Appeals and Interferences**

In re Application of: Brad K. Fayette
Serial No. 09/972,568
Filing Date: October 5, 2001
Confirmation No. 5350
Group Art Unit: 2151
Examiner: Kamal B. Divecha
Title: *Method and System for Communicating Among Heterogeneous Systems*

Mail Stop: Appeal Brief - Patents

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Willie Jiles

Willie Jiles

Date: March 17, 2006

Appeal Brief

Appellants have appealed to the Board of Patent Appeals and Interferences from the decision of the Examiner mailed November 7, 2005, finally rejecting Claims 1-5, 11-17, and 20-22, all of which are pending in this case. Appellants filed a Notice of Appeal on February 7, 2006, along with a Pre-Appeal Brief Request for Review. On March 2, a Notice of Panel Decision from Pre-Appeal Brief Review was mailed indicating that the this case should proceed to the Board. Thus, Appellants respectfully submit this Appeal Brief with the statutory fee of \$500.00.

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Real Party In Interest

This application is currently owned by Fujitsu Limited, as indicated by an assignment recorded on December 6, 2005, in the Assignment Records of the United States Patent and Trademark Office at Reel 017091, Frames 0587-0590.

Related Appeals and Interferences

There are no known appeals or interferences which will directly affect or be directly affected by or have a bearing on the Board's decision regarding this appeal.

Status of Claims

Claims 1-5, 11-17, and 20-22 are pending in this application. Claims 1-5, 11-17, and 20-22 are rejected pursuant to a final Office Action mailed November 7, 2005, and are all presented for appeal. All pending claims are shown in Appendix A.

Status of Amendments

All amendments submitted by Appellants were entered by the Examiner before the issuance of the final Office Action mailed November 7, 2005.

Summary of Claimed Subject Matter

Embodiments of the present invention include a method and system for communications between heterogeneous systems. One embodiment of the method according to the invention describes a stateless protocol method for communicating between software processes in the same or different computing platforms and provides for layered protocols. The method implemented on each platform can permit each platform to convert received data from the format defined for a predetermined type to a format which is convenient to the receiving platform. (¶ 4)

Figure 2 of the present application illustrates a machine having an embodiment of the stateless protocol system 201 according to the invention. The machine can be a computer having a top layer application 202 which provides an interface for communicating over a network. The top layer application generally has a local data structure 211 for defining data according to a local format. Data manipulated by the top layer application 202 can be stored in a local buffer 212 memory device according the local format. The stateless protocol system 201 is provided in communication with the top layer application 202 and provides for conversion of data according to a protocol established by the stateless protocol system 201. The stateless protocol system 201 is provided with a legacy protocol 208 and can also include an upgraded protocol 209 which can be provided in addition to or in place of the legacy protocol 208. The legacy protocol 208 and upgraded protocol 209 define formats for header information in the form of parameters which can provide communication information related to data being sent from one system to another, among other things. The legacy protocol 208 and upgraded protocol 209 can be stored in the memory or otherwise programmed into the stateless protocol system 201 as software or hard coded into logic circuits. (¶ 15)

Figure 3 of the present application illustrates an embodiment of the stateless protocol method. The method can be provided as an software or it can be hard coded into logic circuits of a system. The stateless protocol method establishes (step 301) a legacy protocol 208 by creating a format for a fixed length header as a combination of several parameters. The legacy protocol 208 that is established is initially provided to all instances of the stateless protocol method to be used by upper level machines in the network, such as the sending machine 110 and the receiving machine 140. In this manner, both the sending machine 110

and the receiving machine 140 are provided with a common understanding of the set of legacy parameters that make up a fixed length header according to the protocol. (¶ 18)

The legacy protocol can comprise one or more groups of parameters which when taken together comprise a fixed length header. Each parameter comprises a type and value pair, represented in this example as {type} and {value}, and when provided in combination can be used to define a fixed length header according to one embodiment of the invention. (¶ 19) The stateless protocol method can also establish an upgraded protocol (step 302) in an alternative embodiment. To establish an upgraded protocol, a set of parameters according to the legacy protocol are taken as a base of the header and then additional upgraded parameters for an upgraded version are appended to the legacy parameters. The additional parameters can be added to the end of the header away from the message according to the particular implementation of the protocol. (¶ 20)

The stateless protocol method implemented on the sending machine 110 constructs (step 303) a header intended for the receiving machine 140 based upon the fixed length header format defined by the legacy protocol 208. Alternatively, the header can be constructed according to the upgraded protocol 209. Once the header is created by the stateless protocol of the sending machine 110, the header is appended (step 304) to one end of the data to be sent. (¶ 22)

Figure 4 of the present application shows another embodiment of the stateless protocol method according to the invention. When a receiving machine 140 having a version of the stateless protocol method receives an inbound message (step 401), it can first strip the message of any additional header information associated with intermediate communication protocols of intermediate machines 120. It is believed that intermediate communication protocols between adjacent machines can provide header information including the length of the message being communicated. (¶ 26) In one embodiment of the stateless protocol method implemented on the receiving machine 140, each piece of data of the message packet is pushed (step 403) into in the memory 206 according to the order in which the data was received. Pushing data (step 403) on a memory 206 can have affect of flattening the data. As a result any additional header information, such as may be added by an upgraded version of the stateless protocol, is removed to prevent confusion when such a message is received by a machine having the legacy protocol 208. (¶ 27)

Since the sending machine 110 and receiving machine 140 share a common legacy version of the stateless protocol, the receiving machine 140 expects a message and header of a known length and can allocate a memory 206 of a corresponding depth for receiving the message or specifically for the header. If the receiving machine 140 expects to receive the same fixed format header as that which was sent by the sending machine 110, the length of the message and header received by receiving machine 140 matches the size of the memory 206 or stacks allocated by the stateless protocol implemented on the receiving machine 140. This result can be effected by only interpreting that portion of the header that is consistent with the protocol on the receiving machine 140. After the data has been pushed onto the memory 206, the stateless protocol system can interpret (step 404) the data according to the version of the protocol on that machine. (¶ 28)

The stateless protocol method permits a machine to upgrade its protocol from a legacy version of the stateless protocol to an upgraded version. In addition the stateless protocol method also permits further upgrades from previous upgraded protocols 209. In order to ensure that a receiving machine 140 can understand a header created by either the legacy protocol 208 or the upgraded protocol 209, the stateless protocol system and method may only upgrade a header in a consistent manner. For example, in establishing (step 302) an upgraded protocol 209, the parameters of the existing protocol are continued to be used in forming a header of a message and only additional data items are appended to the existing protocol. Furthermore, any additional parameters can be prepended to the legacy header 208 at the end of the header and away from the message. (¶ 29)

A receiving machine 140 having a legacy version of the stateless protocol can interpret a received message having an upgraded header. The receiving machine 140 expects to receive a message and header of a length set by the legacy format and allocates a memory or stack of corresponding depth. For example, when the receiving machine 140 receives a message, such as {3, 2, a, b, c, d, 1}, the message and header are added to the memory 206 first, and then are followed by the header. Since the memory 206 has been allocated only sufficient storage space for {a, b, c, d, 1} according to the legacy protocol 208, additional parameters of the upgraded header can be stripped off or ignored and the header becomes truncated or flattened. Thus, the parameters {3, 2} provided by the upgraded protocol 209

can be dropped because the memory has become occupied by the legacy protocol 208 which proceeded it. (¶ 30)

Thus, the pushing of data onto memory of a size determined by a legacy protocol 208 at a receiving machine 140 causes the message to be flattened by the memory 206 and thereby preserves only that information understood by the receiving machine 140 having the legacy format of the stateless protocol. As a consequence, the format of the header of sending machine 110 can be upgraded without disturbing the communications to other machines having an earlier version of the stateless protocol implemented in their systems. (¶ 31)

Grounds of Rejection to be Reviewed on Appeal

Appellants request that the Board review the following rejections by the Examiner:

(a) The rejection of Claims 1, 5, 11, 14-15, and 20 under 35 U.S.C. §103(a) as being unpatentable U.S. Patent No. 6,032,197 issued to Birdwell et al. in view of U.S. Patent No. 6,088,197 issued to Hasbun et al.;

(b) The rejection of Claims 2, 12-13, 16 and 21-22 under 35 U.S.C. § 103(a) as being unpatentable over Birdwell in view of Hasbun in view of Deering, IETF RFC-2460 by S. Deering and R. Hinden and in further view of U.S. Patent No. 6,944,168 issued to Paatela et al.;

(c) The rejection of Claims 3 and 17 under 35 U.S.C. § 103(a) as being obvious over Birdwell in view of Hasbun in view of Deering and in further view of Paatela and U.S. Patent No. 5,206,822 issued to Taylor; and

(d) The rejection of Claim 4 under 35 U.S.C. § 103(a) as being obvious over Birdwell in view of Hasbun and in further view of U.S. Patent No. 4,973,952 issued to Malec et al.

Argument

The Examiner's rejections of Claims 1-5, 11-17, and 20-22 are improper, and the Board should withdraw these rejections for the reasons given below.

I. The Examiner's Rejection of Claims 1, 5, 11, 14-15, and 20 is Improper

The Examiner rejects Claims 1-5, 11, 14-15 and 20 under 35 U.S.C. § 103(a) as being unpatentable over U.S. Patent No. 6,032,197 issued to Birdwell et al. ("Birdwell") in view of U.S. Patent No. 6,088,759 issued to Hasbun et al. ("Hasbun").

In order to establish a *prima facie* case of obviousness, three requirements must be met: (1) there must be some suggestion or motivation, either in the references themselves or in the knowledge available to one skilled in the art, to modify a reference or combine multiple references; (2) there must be a reasonable expectation of success; and (3) the prior art reference (or combination of references) must teach or suggest all of the claim limitations. M.P.E.P. § 2143. In the present case, a *prima facie* case of obviousness cannot be maintained at least because *Birdwell* and *Hasbun*, whether considered singly, in combination with one another, or in combination with information generally available to those of ordinary skill in the art at the time of the invention, fail to disclose all of the elements of the pending claims. Furthermore, there is also not a suggestion or motivation to combine these references as proposed by the Examiner.

Claim 1 of the present application recites the following limitations:

A stateless protocol method which is operable on a computer processor and computer memory, the stateless protocol comprising a computer program which configures the computer processor to:

establish a legacy protocol, wherein said legacy protocol defines at least one legacy parameter for a header portion of a message, and wherein said legacy protocol defines a fixed legacy header length;
receive an inbound message having a header portion;
allocate a memory portion from the computer memory, said memory portion having a depth corresponding to said fixed legacy header length;
push said header portion of said inbound message onto said memory portion thereby forming a received header, wherein said header portion is

truncated to form the received header if a length of said header portion is greater than said depth of said memory portion corresponding to said fixed legacy header length, such truncation causing any header parameters associated with an upgraded protocol to be removed from said header portion; and

interpret said received header according to said legacy protocol.

Independent Claims 11, 15 and 20 recite similar, although not identical, limitations.

Appellant respectfully submits that Claim 1 is allowable since the proposed *Birdwell-Hasbun* combination does not disclose, teach, or suggest each and every one of these limitations. For example, the proposed combination does not disclose, teach or suggest “allocat[ing] a memory portion from the computer memory, said memory portion having a depth corresponding to said fixed legacy header length.” The Examiner states in the Final Office Action that this limitation is disclosed at Column 3, lines 3-22 and Column 6, lines 10-21 of *Birdwell*. However, there is no disclosure in these cited passages of a particular depth of the memory, much less that the depth *corresponds to a fixed legacy header length*.

Furthermore, the proposed combination does not disclose, teach, or suggest “push[ing] said header portion of said inbound message onto said memory portion thereby forming a received header, wherein said header portion is truncated to form the received header if a length of said header portion is greater than said depth of said memory portion corresponding to said fixed legacy header length, such truncation causing any header parameters associated with an upgraded protocol to be removed from said header portion.” First, Appellant respectfully disagrees with the Examiner’s statement that the recited upgraded protocol could be interpreted as the legacy protocol. As is clear from this claim (i.e., the use of the two different terms), from its dependent claims (especially Claim 2), and the specification of this application, the legacy protocol is different than the upgraded protocol. Second, although the cited passages in *Birdwell* disclose compressing a header by removing particular “non-changing” header fields, this is not a disclosure of truncating portions of a header that do not fit with a memory portion. The passages cited from *Birdwell* describe communication of packets in a single protocol – UDP/IP. Although packets communicated using this protocol have differing headers (see, e.g., Column 2, lines 33-47),

they use the same protocol. There is no disclosure of header parameters associated with an upgraded protocol, and thus there is no disclosure of the limitations of this claim.

The Examiner goes on to argue that Claim 1 may be interpreted as if the condition "if a length of said header portion is greater than said depth of said memory portion" is not true, which Appellant gathers is why the Examiner states that *Birdwell* discloses this limitation. However, Claim 1 clearly requires a computer program which configures a computer to perform the step of truncating the header portion if this condition is true. This capability is clearly a requirement of the claim and cannot be read out of the claim.

Although arguing this construction of Claim 1, the Examiner also asserts that the above-quoted "pushing" limitation is disclosed in *Hasbun* (at least when the above condition is "true"). However, Appellant cannot see how the cited figures of *Hasbun* disclose allocating a memory depth corresponding to a fixed legacy header length, as asserted by the Examiner, or how these figures discloses or suggest truncating the header portion as claimed. As the Examiner recognizes, *Hasbun* does not disclose truncating a header portion, instead it discloses generating an error if there is insufficient space in a memory for an object. Furthermore, it discloses that if such an error is generated, the memory is not allocated (Column 9, lines 35-40). Thus, it actually teaches away from modifying (for example, truncating) what it trying to be put in memory. For this reason, this teaching of *Hasbun* cannot be properly combined with *Birdwell* to disclose "push[ing] said header portion of said inbound message onto said memory portion thereby forming a received header, wherein said header portion is truncated to form the received header if a length of said header portion is greater than said depth of said memory portion corresponding to said fixed legacy header length, such truncation causing any header parameters associated with an upgraded protocol to be removed from said header portion." Furthermore, as described above, even if these teachings could be combined, *Birdwell* also does not disclose truncating a header portion, and thus this limitation is not disclosed, taught or suggested by the proposed combination of references.

For at least these reasons, Appellant believes Claim 1 to be in condition for allowance. Furthermore, Claims 11, 15 and 20 include similar limitations and thus are allowable for similar reasons. Therefore, Appellant respectfully requests allowance of Claims 1, 11, 15 and 20, as well as the claims that depend from these independent claims.

II. The Examiner's Rejection of Claims 2, 12-13, 16 and 21-22 is Improper

The Examiner also rejects Claims 2, 12-13, 16 and 21-22 under 35 U.S.C. § 103(a) as being unpatentable over *Birdwell* in view of *Hasbun* in view of Deering, IETF RFC-2460 by S. Deering and R. Hinden ("Deering") and in further view of U.S. Patent No. 6,944,168 issued to Paatela et al. ("Paatela").

In addition to depending from an allowable independent claim, Claims 2, 12, 16 and 21 recite additional limitations not disclosed by any of the cited references. For example, *Birdwell* does not disclose an upgraded protocol or that the upgraded protocol includes at least one legacy parameter of a legacy protocol and at least one upgraded header parameter. Again, there are not two different protocols disclosed in *Birdwell*. *Birdwell* discloses compressing the headers of some packets that are communicated using a single protocol (the headers of some packets can be compressed because of repetitive information in the header of each packet). Furthermore, since there is not a disclosure of both a legacy protocol and an upgraded protocol, there is also not a disclosure of any upgraded header parameters or of a memory portion having a depth corresponding to said upgraded header length. The fact that *Birdwell* does not disclose two different protocols is evident by the fact that the Examiner uses the very same passage of *Birdwell* for a disclosure that the memory portion has a depth corresponding to a fixed *legacy* header length and for a disclosure that the memory portion has a depth corresponding to an *upgraded* header length. Again, it is improper to construe a "fixed legacy header length" as being the same thing as an "upgraded header length."

Furthermore, none of the cited references disclose that 1) the received header of an inbound message is interpreted according to an upgraded protocol if at least one upgraded header parameter is pushed on the memory portion, and that 2) the received header of the inbound message is interpreted according to a legacy protocol when no upgraded header

parameters are pushed on the memory portion. As described above, *Birdwell* does not disclose both a legacy protocol and an upgraded protocol, and thus it also cannot disclose these limitations. Furthermore, the Examiner argues that another reference (*Paatela*) discloses interpreting an inbound message according to an upgraded protocol if at least one upgraded header parameter is pushed on the memory portion. However, as with *Birdwell*, *Paatela* does not disclose interpreting an inbound message according to one of two different protocols based on the type of header parameter that is pushed on a memory portion. Appellant respectfully submits that there is no suggestion to modify the teachings of *Birdwell* and *Paatela*, which teach interpreting messages according to a single protocol, to create a teaching of a single system, software or method that can interpret an inbound message according to two different protocols and where the decision regarding which protocol to use is based on the type of header parameters is received. No such disclosure or teaching is found in any of the cited reference and there is no suggestion to modify the teachings of the cited references to disclose such a system, software or method.

Appellant respectfully submits that the Examiner is improperly using hindsight to splice together teachings of numerous references to teach the present invention when there is no suggestion or motivation in the cited prior art to do so. The M.P.E.P. and the Federal Circuit repeatedly warn against using an Appellant's disclosure as a blueprint to reconstruct the claimed invention. For example, the M.P.E.P. states, "The tendency to resort to 'hindsight' based upon Appellant's disclosure is often difficult to avoid due to the very nature of the examination process. However, impermissible hindsight must be avoided and the legal conclusion must be reached on the basis of the facts gleaned from the prior art." M.P.E.P. ch. 2142 (Rev. 2, May 2004). The governing Federal Circuit cases are equally clear.

A critical step in analyzing the patentability of claims pursuant to [35 U.S.C. § 103] is casting the mind back to the time of invention, to consider the thinking of one of ordinary skill in the art, guided only by the prior art references and the then-accepted wisdom in the field. . . . Close adherence to this methodology is especially important in cases where the very ease with which the invention can be understood may prompt one "to fall victim to the insidious effect of a hindsight syndrome wherein that which only the invention taught is used against its teacher."

In re Kotzab, 217 F.3d 1365, 1369, 55 U.S.P.Q.2d 1313, 1316 (Fed. Cir. 2000) (citations omitted).

For at least these additional reasons, Appellant believes Claims 2, 12, 16 and 21 to be in condition for allowance. Therefore, Appellant respectfully requests reconsideration and allowance of Claims 2, 12, 16 and 21. Furthermore, Claims 13 and 22 depend from Claims 12 and 21, respectively, and are allowable at least due to their dependence on an allowable claim.

III. The Examiner's Rejection of Claims 3, 4 and 17 is Improper

The Examiner rejects Claims 3 and 17 under 35 U.S.C. § 103(a) as being obvious over *Birdwell* in view of *Hasbun* in view of *Deering* and in further view of *Paatela* and U.S. Patent No. 5,206,822 issued to Taylor ("Taylor"). The Examiner also rejects Claim 4 under 35 U.S.C. § 103(a) as being obvious over *Birdwell* in view of *Hasbun* and in further view of U.S. Patent No. 4,973,952 issued to Malec et al. ("Malec").

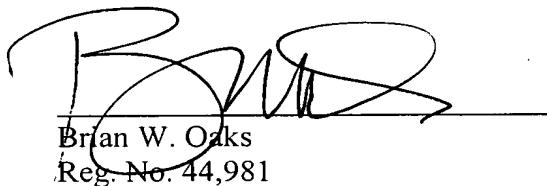
Each of these claims depends from one of independent Claims 1 or 15. As discussed above, Appellant believes these independent claims to be in condition for allowance. Therefore, Claims 3, 4 and 17 are allowable at least because they depend from an allowable independent claim. Therefore, Appellant respectfully requests reconsideration and allowance of Claims 3, 4 and 17.

Conclusion

Appellants have demonstrated that the present invention, as claimed, is clearly distinguishable over the prior art cited by the Examiner. Therefore, Appellants respectfully request the Board of Patent Appeals and Interferences to reverse the final rejection of the Examiner and instruct the Examiner to issue a notice of allowance of all claims.

Appellants have enclosed a check in the amount of \$500.00 for this Appeal Brief. Appellants believe no additional fees are due. The Commissioner is hereby authorized to charge any fee and credit any overpayment to Deposit Account No. 02-0384 of Baker Botts L.L.P.

Respectfully submitted,
BAKER BOTTs L.L.P.
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Date: March 17, 2006

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Appendix A: Claims on Appeal

1. (Previously Presented) A stateless protocol method which is operable on a computer processor and computer memory, the stateless protocol comprising a computer program which configures the computer processor to:

establish a legacy protocol, wherein said legacy protocol defines at least one legacy parameter for a header portion of a message, and wherein said legacy protocol defines a fixed legacy header length;

receive an inbound message having a header portion;

allocate a memory portion from the computer memory, said memory portion having a depth corresponding to said fixed legacy header length;

push said header portion of said inbound message onto said memory portion thereby forming a received header, wherein said header portion is truncated to form the received header if a length of said header portion is greater than said depth of said memory portion corresponding to said fixed legacy header length, such truncation causing any header parameters associated with an upgraded protocol to be removed from said header portion; and interpret said received header according to said legacy protocol.

2. (Previously Presented) The stateless protocol method according to claim 1, further comprising a computer program which configures the computer processor to:

establish said upgraded protocol, wherein said upgraded protocol includes said at least one legacy parameter of said legacy protocol, wherein said upgraded protocol defines at least one upgraded header parameter for said header portion, and wherein said upgraded protocol defines a fixed upgraded header length;

wherein said memory portion has a depth corresponding to said upgraded header length;

wherein said received header of said inbound message is interpreted according to said upgraded protocol if at least one upgraded header parameter is pushed on the memory portion; and

wherein said received header of said inbound message is interpreted according to said legacy protocol when no upgraded header parameters are pushed on the memory portion.

3. (Original) The stateless protocol method according to claim 2 further comprising a computer program which configures the computer processor to:

pad said memory portion with default padding values when said header portion of said inbound message does not fill said memory portion.

4. (Original) The stateless protocol method according to claim 1, wherein said legacy parameter comprises a value-type pair.

5. (Original) The stateless protocol method according to claim 1, wherein said inbound message includes a data portion and wherein said header portion is pushed onto said memory portion after said data portion.

6. (Canceled)

7. (Canceled)

8. (Canceled)

9. (Canceled)

10. (Canceled)

11. (Previously Presented) A stateless protocol method which is operable on a computer processor and computer memory, the stateless protocol comprising a computer program which configures the computer processor to:

establish a legacy protocol, wherein said legacy protocol defines at least one legacy parameter for a header portion of a message, and wherein said legacy protocol defines a fixed legacy header length;

receive an inbound message having a header portion;

allocate a memory portion from the computer memory, said memory portion having a depth corresponding to said fixed legacy header length;

push said header portion of said inbound message onto said memory portion thereby forming a received header, wherein said header portion is truncated to form the received header if a length of said header portion is greater than said depth of said memory portion corresponding to said fixed legacy header length, such truncation causing any header parameters associated with an upgraded protocol to be removed from said header portion;

interpret said received header according to said legacy protocol;

construct a legacy header according to said legacy protocol;

append said legacy header to outbound data thereby creating an outbound message; and

send said outbound message.

12. (Previously Presented) The stateless protocol method according to claim 11, further comprising a computer program which configures the computer processor to:

establish said upgraded protocol, wherein said upgraded protocol includes said at least one legacy parameter of said legacy protocol, wherein said upgraded protocol defines at least one upgraded header parameter, and wherein said upgraded protocol defines a fixed upgraded header length;

wherein said memory portion has a depth corresponding to said upgraded header length;

wherein said received header of said inbound message is interpreted according to said upgraded protocol if at least one upgraded header parameter is pushed on the memory stack;

wherein said received header of said inbound message is interpreted according to said legacy protocol if no upgraded header parameters are pushed on the memory stack;

construct an upgraded header according to said upgraded protocol; and

append said upgraded header to outbound data.

13. (Previously Presented) The stateless protocol method according to claim 12 further comprising a computer program which configures the computer processor to push said legacy parameter onto said memory portion before said upgraded parameter is pushed onto said memory portion.

14. (Original) The stateless protocol method according to claim 11 further comprising a computer program which configures the computer processor to:

receive said inbound message from an upper layer application having a header portion in an upper layer format; and

send said outbound message to a lower layer application.

15. (Previously Presented) A stateless protocol system for processing at least one inbound message, the system comprising:

a computer memory; and

a computer processor, said processor being programmed to establish a legacy protocol, wherein said legacy protocol defines at least one legacy parameter for a header portion of a message, and wherein said legacy protocol defines a fixed legacy header length;

allocate a memory portion from the computer memory, said memory portion having a depth corresponding to said fixed legacy header length;

push said header portion of said inbound message onto said memory portion wherein said data portion is pushed onto said stack first, wherein said header portion is truncated to form the received header if a length of said header portion is greater than said depth of said memory portion corresponding to said fixed legacy header length, such truncation causing any header parameters associated with an upgraded protocol to be removed from said header portion; and

interpret said received header according to said legacy protocol.

16. (Previously Presented) The stateless protocol system according to claim 15, wherein said processor is further programmed to:

establish said upgraded protocol, wherein said upgraded protocol includes said at least one legacy parameters of said legacy protocol, wherein said upgraded protocol defines at least one upgraded header parameter, and wherein said upgraded protocol defines a fixed upgraded header length;

wherein said memory portion has a depth corresponding to said upgraded header length;

wherein said portion of said message is interpreted according to said upgraded protocol if at least one upgraded header parameter is pushed onto said memory portion; and

wherein said portion of said message is interpreted according to said legacy protocol if no upgraded header parameters are pushed onto said memory portion.

17. (Original) The stateless protocol system according to claim 16 wherein said processor is further programmed to pad said memory portion with default padding values when said message does not fill said memory portion.

18. (Canceled)

19. (Canceled)

20. (Previously Presented) A stateless protocol system for processing inbound and outbound messages, the system comprising:

a computer memory; and

a computer processor, said processor being programmed to

establish a legacy protocol, wherein said legacy protocol defines at least one legacy parameter for a header portion of inbound and outbound messages, and wherein said legacy protocol defines a fixed legacy message length;

receive an inbound message having a data portion;

allocate a memory stack from said computer memory, said memory stack having a depth corresponding to said fixed legacy message length;

push said inbound message onto said memory stack thereby forming at least a portion of said inbound message, wherein said data portion is pushed onto said stack proximate to a bottom of said stack, also wherein said header portion is truncated to form the received header if a length of said header portion is greater than said depth of said memory portion corresponding to said fixed legacy header length, such truncation causing any header parameters associated with an upgraded protocol to be removed from said header portion;

interpret said portion of said inbound message according to said legacy protocol;

construct a legacy header according to said legacy protocol;

append said legacy header to outbound data thereby creating an outbound message of said fixed legacy message length; and

send said outbound message.

21. (Previously Presented) The stateless protocol system according to claim 20, wherein said processor is further programmed to:

establish said upgraded protocol, wherein said upgraded protocol includes said at least one legacy parameter of said legacy protocol, wherein said upgraded protocol defines at least one upgraded header parameter, and wherein said upgraded protocol defines a fixed upgraded message length;

wherein said memory stack has a depth corresponding to said upgraded message length;

wherein said portion of said inbound message is interpreted according to said upgraded protocol if at least one upgraded header parameter is pushed onto said memory stack;

wherein said portion of said inbound message is interpreted according to said legacy protocol if no upgraded header parameters are pushed onto said memory stack;

construct an upgraded header according to said upgraded protocol; and

append said upgraded header to outbound data, wherein said at least one legacy parameter is proximate to said outbound data, thereby creating an outbound message of said fixed upgraded message length.

22. (Original) The stateless protocol method according to claim 21 wherein said processor is further programmed to:

receive said inbound message from an upper layer application having a data portion in an upper layer format; and

send said outbound message to a lower layer application.

Appendix B: Evidence

ATTACHED

Appendix C: Related Proceedings

NONE

Network Working Group
Request for Comments: 2460
Obsoletes: 1883
Category: Standards Track

S. Deering
Cisco
R. Hinden
Nokia
December 1998

Internet Protocol, Version 6 (IPv6)
Specification

Status of this Memo

This document specifies an Internet standards track protocol for the Internet community, and requests discussion and suggestions for improvements. Please refer to the current edition of the "Internet Official Protocol Standards" (STD 1) for the standardization state and status of this protocol. Distribution of this memo is unlimited.

Copyright Notice

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Abstract

This document specifies version 6 of the Internet Protocol (IPv6), also sometimes referred to as IP Next Generation or IPng.

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1. Introduction

IP version 6 (IPv6) is a new version of the Internet Protocol, designed as the successor to IP version 4 (IPv4) [RFC-791]. The changes from IPv4 to IPv6 fall primarily into the following categories:

- o Expanded Addressing Capabilities

IPv6 increases the IP address size from 32 bits to 128 bits, to support more levels of addressing hierarchy, a much greater number of addressable nodes, and simpler auto-configuration of addresses. The scalability of multicast routing is improved by adding a "scope" field to multicast addresses. And a new type of address called an "anycast address" is defined, used to send a packet to any one of a group of nodes.

- o Header Format Simplification

Some IPv4 header fields have been dropped or made optional, to reduce the common-case processing cost of packet handling and to limit the bandwidth cost of the IPv6 header.

- o Improved Support for Extensions and Options

Changes in the way IP header options are encoded allows for more efficient forwarding, less stringent limits on the length of options, and greater flexibility for introducing new options in the future.

- o Flow Labeling Capability

A new capability is added to enable the labeling of packets belonging to particular traffic "flows" for which the sender requests special handling, such as non-default quality of service or "real-time" service.

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- o Authentication and Privacy Capabilities

Extensions to support authentication, data integrity, and (optional) data confidentiality are specified for IPv6.

This document specifies the basic IPv6 header and the initially-defined IPv6 extension headers and options. It also discusses packet size issues, the semantics of flow labels and traffic classes, and the effects of IPv6 on upper-layer protocols. The format and semantics of IPv6 addresses are specified separately in [ADDRARCH]. The IPv6 version of ICMP, which all IPv6 implementations are required to include, is specified in [ICMPv6].

2. Terminology

node - a device that implements IPv6.

router - a node that forwards IPv6 packets not explicitly

addressed to it. [See Note below].

host - any node that is not a router. [See Note below].

upper layer - a protocol layer immediately above IPv6. Examples are transport protocols such as TCP and UDP, control protocols such as ICMP, routing protocols such as OSPF, and internet or lower-layer protocols being "tunneled" over (i.e., encapsulated in) IPv6 such as IPX, AppleTalk, or IPv6 itself.

link - a communication facility or medium over which nodes can communicate at the link layer, i.e., the layer immediately below IPv6. Examples are Ethernets (simple or bridged); PPP links; X.25, Frame Relay, or ATM networks; and internet (or higher) layer "tunnels", such as tunnels over IPv4 or IPv6 itself.

neighbors - nodes attached to the same link.

interface - a node's attachment to a link.

address - an IPv6-layer identifier for an interface or a set of interfaces.

packet - an IPv6 header plus payload.

link MTU - the maximum transmission unit, i.e., maximum packet size in octets, that can be conveyed over a link.

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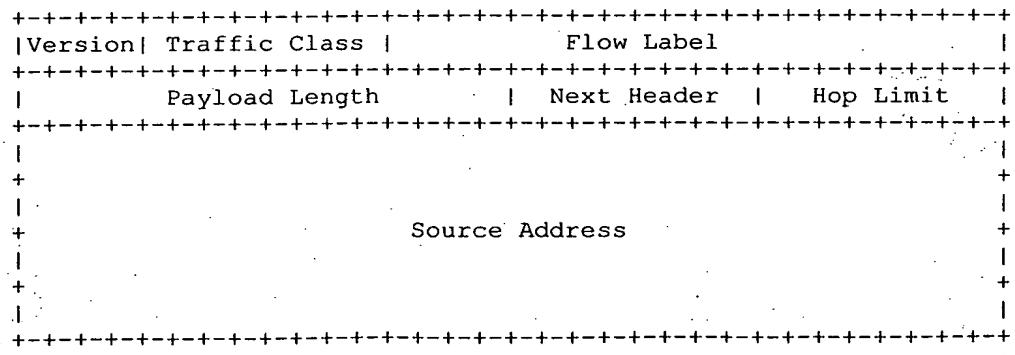
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path MTU - the minimum link MTU of all the links in a path between a source node and a destination node.

Note: it is possible, though unusual, for a device with multiple interfaces to be configured to forward non-self-destined packets arriving from some set (fewer than all) of its interfaces, and to discard non-self-destined packets arriving from its other interfaces. Such a device must obey the protocol requirements for routers when receiving packets from, and interacting with neighbors over, the former (forwarding) interfaces. It must obey the protocol requirements for hosts when receiving packets from, and interacting with neighbors over, the latter (non-forwarding) interfaces.

3. IPv6 Header Format



Destination Address

Version	4-bit Internet Protocol version number = 6..
Traffic Class	8-bit traffic class field. See section 7.
Flow Label	20-bit flow label. See section 6.
Payload Length	16-bit unsigned integer. Length of the IPv6 payload, i.e., the rest of the packet following this IPv6 header, in octets. (Note that any

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extension headers [section 4] present are considered part of the payload, i.e., included in the length count.)

Next Header 8-bit selector. Identifies the type of header immediately following the IPv6 header. Uses the same values as the IPv4 Protocol field [RFC-1700 et seq.].

Hop Limit 8-bit unsigned integer. Decrement by 1 by each node that forwards the packet. The packet is discarded if Hop Limit is decremented to zero.

Source Address 128-bit address of the originator of the packet. See [ADDRARCH].

Destination Address 128-bit address of the intended recipient of the packet (possibly not the ultimate recipient, if a Routing header is present). See [ADDRARCH] and section 4.4.

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4. IPv6 Extension Headers

In IPv6, optional internet-layer information is encoded in separate headers that may be placed between the IPv6 header and the upper-layer header in a packet. There are a small number of such extension headers, each identified by a distinct Next Header value. As illustrated in these examples, an IPv6 packet may carry zero, one, or more extension headers, each identified by the Next Header field of the preceding header:

```
+-----+-----+  
| IPv6 header | TCP header + data  
|             |  
| Next Header = |  
|     TCP       |  
+-----+-----+
```

```
+-----+-----+-----+  
| IPv6 header | Routing header | TCP header + data  
|             |             |  
| Next Header = | Next Header = |  
|     Routing   |     TCP       |  
+-----+-----+-----+
```

```
+-----+-----+-----+-----+  
| IPv6 header | Routing header | Fragment header | fragment of TCP  
|             |             |             | header + data  
| Next Header = | Next Header = | Next Header = |  
|     Routing   |     Fragment |     TCP       |  
+-----+-----+-----+-----+
```

With one exception, extension headers are not examined or processed by any node along a packet's delivery path, until the packet reaches the node (or each of the set of nodes, in the case of multicast) identified in the Destination Address field of the IPv6 header. There, normal demultiplexing on the Next Header field of the IPv6 header invokes the module to process the first extension header, or the upper-layer header if no extension header is present. The contents and semantics of each extension header determine whether or not to proceed to the next header. Therefore, extension headers must be processed strictly in the order they appear in the packet; a receiver must not, for example, scan through a packet looking for a particular kind of extension header and process that header prior to processing all preceding ones.

The exception referred to in the preceding paragraph is the Hop-by-Hop Options header, which carries information that must be examined and processed by every node along a packet's delivery path, including the source and destination nodes. The Hop-by-Hop Options header, when present, must immediately follow the IPv6 header. Its presence is indicated by the value zero in the Next Header field of the IPv6 header.

If, as a result of processing a header, a node is required to proceed to the next header but the Next Header value in the current header is unrecognized by the node, it should discard the packet and send an ICMP Parameter Problem message to the source of the packet, with an ICMP Code value of 1 ("unrecognized Next Header type encountered") and the ICMP Pointer field containing the offset of the unrecognized value within the original packet. The same action should be taken if a node encounters a Next Header value of zero in any header other than an IPv6 header.

Each extension header is an integer multiple of 8 octets long, in order to retain 8-octet alignment for subsequent headers. Multi-octet fields within each extension header are aligned on their natural boundaries, i.e., fields of width n octets are placed at an integer multiple of n octets from the start of the header, for $n = 1, 2, 4$, or 8 .

A full implementation of IPv6 includes implementation of the following extension headers:

Hop-by-Hop Options
Routing (Type 0)
Fragment
Destination Options
Authentication
Encapsulating Security Payload

The first four are specified in this document; the last two are specified in [RFC-2402] and [RFC-2406], respectively.

4.1 Extension Header Order

When more than one extension header is used in the same packet, it is recommended that those headers appear in the following order:

IPv6 header
Hop-by-Hop Options header
Destination Options header (note 1)
Routing header
Fragment header

Authentication header (note 2)
Encapsulating Security Payload header (note 2)
Destination Options header (note 3)
upper-layer header

note 1: for options to be processed by the first destination

that appears in the IPv6 Destination Address field plus subsequent destinations listed in the Routing header.

note 2: additional recommendations regarding the relative order of the Authentication and Encapsulating Security Payload headers are given in [RFC-2406].

note 3: for options to be processed only by the final destination of the packet.

Each extension header should occur at most once, except for the Destination Options header which should occur at most twice (once before a Routing header and once before the upper-layer header).

If the upper-layer header is another IPv6 header (in the case of IPv6 being tunneled over or encapsulated in IPv6), it may be followed by its own extension headers, which are separately subject to the same ordering recommendations.

If and when other extension headers are defined, their ordering constraints relative to the above listed headers must be specified.

IPv6 nodes must accept and attempt to process extension headers in any order and occurring any number of times in the same packet, except for the Hop-by-Hop Options header which is restricted to appear immediately after an IPv6 header only. Nonetheless, it is strongly advised that sources of IPv6 packets adhere to the above recommended order until and unless subsequent specifications revise that recommendation.

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4.2 Options

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4.2 Options

Two of the currently-defined extension headers -- the Hop-by-Hop Options header and the Destination Options header -- carry a variable number of type-length-value (TLV) encoded "options", of the following format:

Option Type	Opt Data Len	Option Data
-------------	--------------	-------------

Option Type 8-bit identifier of the type of option.

Opt Data Len 8-bit unsigned integer. Length of the Option Data field of this option, in octets.

The sequence of options within a header must be processed strictly in the order they appear in the header; a receiver must not, for example, scan through the header looking for a particular kind of option and process that option prior to processing all preceding ones.

The Option Type identifiers are internally encoded such that their highest-order two bits specify the action that must be taken if the processing IPv6 node does not recognize the Option Type:

- 00 - skip over this option and continue processing the header.
- 01 - discard the packet.
- 10 - discard the packet and, regardless of whether or not the packet's Destination Address was a multicast address, send an ICMP Parameter Problem, Code 2, message to the packet's Source Address, pointing to the unrecognized Option Type.
- 11 - discard the packet and, only if the packet's Destination Address was not a multicast address, send an ICMP Parameter Problem, Code 2, message to the packet's Source Address, pointing to the unrecognized Option Type.

The third-highest-order bit of the Option Type specifies whether or not the Option Data of that option can change en-route to the packet's final destination. When an Authentication header is present

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in the packet, for any option whose data may change en-route, its entire Option Data field must be treated as zero-valued octets when computing or verifying the packet's authenticating value.

- 0 - Option Data does not change en-route
- 1 - Option Data may change en-route

The three high-order bits described above are to be treated as part of the Option Type, not independent of the Option Type. That is, a particular option is identified by a full 8-bit Option Type, not just the low-order 5 bits of an Option Type.

The same Option Type numbering space is used for both the Hop-by-Hop Options header and the Destination Options header. However, the specification of a particular option may restrict its use to only one of those two headers.

Individual options may have specific alignment requirements, to ensure that multi-octet values within Option Data fields fall on natural boundaries. The alignment requirement of an option is specified using the notation $xn+y$, meaning the Option Type must appear at an integer multiple of x octets from the start of the header, plus y octets. For example:

- $2n$ means any 2-octet offset from the start of the header.
- $8n+2$ means any 8-octet offset from the start of the header, plus 2 octets.

There are two padding options which are used when necessary to align subsequent options and to pad out the containing header to a multiple of 8 octets in length. These padding options must be recognized by all IPv6 implementations:

Pad1 option (alignment requirement: none)

+-+-+-+--+
| 0 |
+-+-+-+--+

NOTE! the format of the Pad1 option is a special case -- it does not have length and value fields.

The Pad1 option is used to insert one octet of padding into the Options area of a header. If more than one octet of padding is required, the PadN option, described next, should be used, rather than multiple Pad1 options.

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PadN option (alignment requirement: none)

	Opt	Data	Len	Option	Data
--	-----	------	-----	--------	------

The PadN option is used to insert two or more octets of padding into the Options area of a header. For N octets of padding, the Opt Data Len field contains the value N-2, and the Option Data consists of N-2 zero-valued octets.

Appendix B contains formatting guidelines for designing new options.

4.3 Hop-by-Hop Options Header

The Hop-by-Hop Options header is used to carry optional information that must be examined by every node along a packet's delivery path. The Hop-by-Hop Options header is identified by a Next Header value of 0 in the IPv6 header, and has the following format:

Next Header	8-bit selector. Identifies the type of header immediately following the Hop-by-Hop Options header. Uses the same values as the IPv4 Protocol field [RFC-1700 et seq.].
Hdr Ext Len	8-bit unsigned integer. Length of the Hop-by-Hop Options header in 8-octet units, not including the first 8 octets.

Options Variable-length field, of length such that the complete hop-by-Hop Options header is an integer multiple of 8 octets long. Contains one or more TLV-encoded options, as described in section 4.2.

The only hop-by-hop options defined in this document are the Pad1 and PadN options specified in section 4.2.

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4.4 Routing Header

The Routing header is used by an IPv6 source to list one or more intermediate nodes to be "visited" on the way to a packet's destination. This function is very similar to IPv4's Loose Source and Record Route option. The Routing header is identified by a Next Header value of 43 in the immediately preceding header, and has the following format:

```
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+  
| Next Header | Hdr Ext Len | Routing Type | Segments Left |  
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+  
|  
|  
| type-specific data  
|  
|  
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+  
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
```

Next Header 8-bit selector. Identifies the type of header immediately following the Routing header. Uses the same values as the IPv4 Protocol field [RFC-1700 et seq.].

Hdr Ext Len 8-bit unsigned integer. Length of the Routing header in 8-octet units, not including the first 8 octets.

Routing Type 8-bit identifier of a particular Routing header variant.

Segments Left 8-bit unsigned integer. Number of route segments remaining, i.e., number of explicitly listed intermediate nodes still to be visited before reaching the final destination.

type-specific data Variable-length field, of format determined by the Routing Type, and of length such that the complete Routing header is an integer multiple of 8 octets long.

If, while processing a received packet, a node encounters a Routing header with an unrecognized Routing Type value, the required behavior of the node depends on the value of the Segments Left field, as follows:

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If Segments Left is zero, the node must ignore the Routing header and proceed to process the next header in the packet, whose type is identified by the Next Header field in the Routing header.

If Segments Left is non-zero, the node must discard the packet and send an ICMP Parameter Problem, Code 0, message to the packet's Source Address, pointing to the unrecognized Routing Type.

If, after processing a Routing header of a received packet, an intermediate node determines that the packet is to be forwarded onto a link whose link MTU is less than the size of the packet, the node must discard the packet and send an ICMP Packet Too Big message to the packet's Source Address.

The Type 0 Routing header has the following format:

+-----+ Next Header Hdr Ext Len Routing Type=0 Segments Left +-----+
--

Next Header 8-bit selector. Identifies the type of header immediately following the Routing header. Uses the same values as the IPv4 Protocol field [RFC-1700 et seq.].

Hdr Ext Len 8-bit unsigned integer. Length of the Routing header in 8-octet units, not including the first 8 octets. For the Type 0 Routing header, Hdr Ext Len is equal to two times the number of addresses in the header.

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Segments Left 8-bit unsigned integer. Number of route segments remaining, i.e., number of explicitly listed intermediate nodes still to be visited before reaching the final destination.

Reserved 32-bit reserved field. Initialized to zero for transmission; ignored on reception.

Address[1..n] Vector of 128-bit addresses, numbered 1 to n.

Multicast addresses must not appear in a Routing header of Type 0, or in the IPv6 Destination Address field of a packet carrying a Routing header of Type 0.

A Routing header is not examined or processed until it reaches the node identified in the Destination Address field of the IPv6 header.

In that node, dispatching on the Next Header field of the immediately preceding header causes the Routing header module to be invoked, which, in the case of Routing Type 0, performs the following algorithm:

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```
if Segments Left = 0 {
    proceed to process the next header in the packet, whose type is
    identified by the Next Header field in the Routing header
}
else if Hdr Ext Len is odd {
    send an ICMP Parameter Problem, Code 0, message to the Source
    Address, pointing to the Hdr Ext Len field, and discard the
    packet
}
else {
    compute n, the number of addresses in the Routing header, by
    dividing Hdr Ext Len by 2

    if Segments Left is greater than n {
        send an ICMP Parameter Problem, Code 0, message to the Source
        Address, pointing to the Segments Left field, and discard the
        packet
    }
    else {
        decrement Segments Left by 1;
        compute i, the index of the next address to be visited in
        the address vector, by subtracting Segments Left from n

        if Address [i] or the IPv6 Destination Address is multicast {
            discard the packet
        }
        else {
```

```
    swap the IPv6 Destination Address and Address[i]

    if the IPv6 Hop Limit is less than or equal to 1 {
        send an ICMP Time Exceeded -- Hop Limit Exceeded in
        Transit message to the Source Address and discard the
        packet
    }
    else {
        decrement the Hop Limit by 1
        resubmit the packet to the IPv6 module for transmission
        to the new destination
    }
}
```

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As an example of the effects of the above algorithm, consider the case of a source node S sending a packet to destination node D, using a Routing header to cause the packet to be routed via intermediate nodes I1, I2, and I3. The values of the relevant IPv6 header and Routing header fields on each segment of the delivery path would be as follows:

As the packet travels from S to II:

Source Address = S
Destination Address = II

```
  Hdr Ext Len = 6
  Segments Left = 3
  Address[1] = I2
  Address[2] = I3
  Address[3] = D
```

As the packet travels from I1 to I2:

Source Address = S
Destination Address = I2

```
  Hdr Ext Len = 6
  Segments Left = 2
  Address[1] = I1
  Address[2] = I3
  Address[3] = D
```

As the packet travels from I2 to I3:

Source Address = S
Destination Address = I3

```
  Hdr Ext Len = 6
  Segments Left = 1
  Address[1] = I1
  Address[2] = I2
  Address[3] = D
```

As the packet travels from I3 to P:

Source Address = S
Destination Address = D

```
  Hdr Ext Len = 6
  Segments Left = 0
  Address[1] = I1
  Address[2] = I2
  Address[3] = I3
```

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4.5 Fragment Header

The Fragment header is used by an IPv6 source to send a packet larger than would fit in the path MTU to its destination. (Note: unlike IPv4, fragmentation in IPv6 is performed only by source nodes, not by routers along a packet's delivery path -- see section 5.) The Fragment header is identified by a Next Header value of 44 in the immediately preceding header, and has the following format:

	Format	Description
Next Header	8-bit selector. Identifies the initial header type of the Fragmentable Part of the original packet (defined below). Uses the same values as the IPv4 Protocol field [RFC-1700 et seq.].	
Reserved	8-bit reserved field. Initialized to zero for transmission; ignored on reception.	
Fragment Offset	13-bit unsigned integer. The offset, in 8-octet units, of the data following this header, relative to the start of the Fragmentable Part of the original packet.	
Res	2-bit reserved field. Initialized to zero for transmission; ignored on reception.	
M flag	1 = more fragments; 0 = last fragment.	
Identification	32 bits. See description below.	

In order to send a packet that is too large to fit in the MTU of the path to its destination, a source node may divide the packet into fragments and send each fragment as a separate packet, to be reassembled at the receiver.

For every packet that is to be fragmented, the source node generates an Identification value. The Identification must be different than that of any other fragmented packet sent recently* with the same Source Address and Destination Address. If a Routing header is present, the Destination Address of concern is that of the final destination.

* "recently" means within the maximum likely lifetime of a packet, including transit time from source to destination and time spent awaiting reassembly with other fragments of the same packet. However, it is not required that a source node know the maximum packet lifetime. Rather, it is assumed that the requirement can be met by maintaining the Identification value as a simple, 32-bit, "wrap-around" counter, incremented each time a packet must be fragmented. It is an implementation choice whether to maintain a single counter for the node or multiple counters, e.g., one for each of the node's possible source addresses, or one for each active (source address, destination address) combination.

The initial, large, unfragmented packet is referred to as the "original packet", and it is considered to consist of two parts, as illustrated:

original packet:

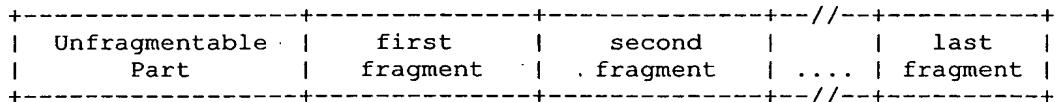


The Unfragmentable Part consists of the IPv6 header plus any extension headers that must be processed by nodes en route to the destination, that is, all headers up to and including the Routing header if present, else the Hop-by-Hop Options header if present, else no extension headers.

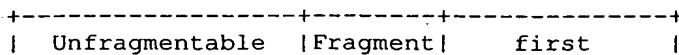
The Fragmentable Part consists of the rest of the packet, that is, any extension headers that need be processed only by the final destination node(s), plus the upper-layer header and data.

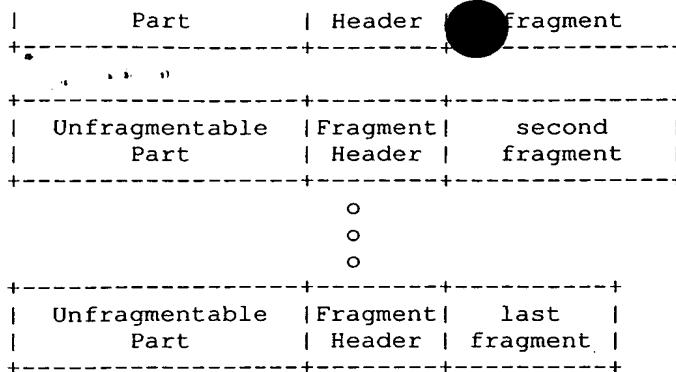
The Fragmentable Part of the original packet is divided into fragments, each, except possibly the last ("rightmost") one, being an integer multiple of 8 octets long. The fragments are transmitted in separate "fragment packets" as illustrated:

original packet:



fragment packets:





Each fragment packet is composed of:

- (1) The Unfragmentable Part of the original packet, with the Payload Length of the original IPv6 header changed to contain the length of this fragment packet only (excluding the length of the IPv6 header itself), and the Next Header field of the last header of the Unfragmentable Part changed to 44.
- (2) A Fragment header containing:

The Next Header value that identifies the first header of the Fragmentable Part of the original packet.

A Fragment Offset containing the offset of the fragment, in 8-octet units, relative to the start of the Fragmentable Part of the original packet. The Fragment Offset of the first ("leftmost") fragment is 0.

An M flag value of 0 if the fragment is the last ("rightmost") one, else an M flag value of 1.

The Identification value generated for the original packet.

- (3) The fragment itself.

The lengths of the fragments must be chosen such that the resulting fragment packets fit within the MTU of the path to the packets' destination(s).

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At the destination, fragment packets are reassembled into their original, unfragmented form, as illustrated:

reassembled original packet:



The following rules govern reassembly:

An original packet is reassembled only from fragment packets that have the same Source Address, Destination Address, and Fragment Identification.

- The Unfragmentable Part of the reassembled packet consists of all headers up to, but not including, the Fragment header of the first fragment packet (that is, the packet whose Fragment Offset is zero), with the following two changes:

The Next Header field of the last header of the Unfragmentable Part is obtained from the Next Header field of the first fragment's Fragment header.

The Payload Length of the reassembled packet is computed from the length of the Unfragmentable Part and the length and offset of the last fragment. For example, a formula for computing the Payload Length of the reassembled original packet is:

```
PL.orig = PL.first - FL.first - 8 + (8 * FO.last) + FL.last
```

where

PL.orig = Payload Length field of reassembled packet.
PL.first = Payload Length field of first fragment packet.
FL.first = length of fragment following Fragment header of first fragment packet.
FO.last = Fragment Offset field of Fragment header of last fragment packet.
FL.last = length of fragment following Fragment header of last fragment packet.

The Fragmentable Part of the reassembled packet is constructed from the fragments following the Fragment headers in each of the fragment packets. The length of each fragment is computed by subtracting from the packet's Payload Length the length of the

headers between the IPv6 header and fragment itself; its relative position in Fragmentable Part is computed from its Fragment Offset value.

The Fragment header is not present in the final, reassembled packet.

The following error conditions may arise when reassembling fragmented packets:

If insufficient fragments are received to complete reassembly of a packet within 60 seconds of the reception of the first-arriving fragment of that packet, reassembly of that packet must be abandoned and all the fragments that have been received for that packet must be discarded. If the first fragment (i.e., the one with a Fragment Offset of zero) has been received, an ICMP Time Exceeded -- Fragment Reassembly Time Exceeded message should be sent to the source of that fragment.

If the length of a fragment, as derived from the fragment packet's Payload Length field, is not a multiple of 8 octets and the M flag of that fragment is 1, then that fragment must be discarded and an ICMP Parameter Problem, Code 0, message should be sent to the source of the fragment, pointing to the Payload Length field of the fragment packet.

If the length and offset of a fragment are such that the Payload Length of the packet reassembled from that fragment would exceed 65,535 octets, then that fragment must be discarded and an ICMP Parameter Problem, Code 0, message should be sent to the source of the fragment, pointing to the Fragment Offset field of the fragment packet.

The following conditions are not expected to occur, but are not considered errors if they do:

The number and content of the headers preceding the Fragment header of different fragments of the same original packet may differ. Whatever headers are present, preceding the Fragment header in each fragment packet, are processed when the packets arrive, prior to queueing the fragments for reassembly. Only those headers in the Offset zero fragment packet are retained in the reassembled packet.

The Next Header values in the Fragment headers of different fragments of the same original packet may differ. Only the value from the Offset zero fragment packet is used for reassembly.

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4.6 Destination Options Header

The Destination Options header is used to carry optional information that need be examined only by a packet's destination node(s). The Destination Options header is identified by a Next Header value of 60 in the immediately preceding header, and has the following format:

Next Header 8-bit selector. Identifies the type of header immediately following the Destination Options header. Uses the same values as the IPv4 Protocol field [RFC-1700 et seq.].

Dest Options Len 8-bit unsigned integer. Length of the Destination Options header in 8-octet units, not including the first 8 octets.

Options Variable-length field, of length such that the complete Destination Options header is an integer multiple of 8 octets long. Contains one or more TLV-encoded options, as described in section 4.2.

The only destination options defined in this document are the Pad1 and PadN options specified in section 4.2.

Note that there are two possible ways to encode optional destination information in an IPv6 packet: either as an option in the Destination

Options header, or as a separate extension header. The Fragment header and the Authentication header are examples of the latter approach. Which approach can be used depends on what action is desired of a destination node that does not understand the optional information:

- o If the desired action is for the destination node to discard the packet and, only if the packet's Destination Address is not a multicast address, send an ICMP Unrecognized Type message to the packet's Source Address, then the information may be encoded either as a separate header or as an option in the

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Destination Options header whose Option Type has the value 11 in its highest-order two bits. The choice may depend on such factors as which takes fewer octets, or which yields better alignment or more efficient parsing.

- o If any other action is desired, the information must be encoded as an option in the Destination Options header whose Option Type has the value 00, 01, or 10 in its highest-order two bits, specifying the desired action (see section 4.2).

4.7 No Next Header

The value 59 in the Next Header field of an IPv6 header or any extension header indicates that there is nothing following that header. If the Payload Length field of the IPv6 header indicates the presence of octets past the end of a header whose Next Header field contains 59, those octets must be ignored, and passed on unchanged if the packet is forwarded.

5. Packet Size Issues

IPv6 requires that every link in the internet have an MTU of 1280 octets or greater. On any link that cannot convey a 1280-octet packet in one piece, link-specific fragmentation and reassembly must be provided at a layer below IPv6.

Links that have a configurable MTU (for example, PPP links [RFC-1661]) must be configured to have an MTU of at least 1280 octets; it is recommended that they be configured with an MTU of 1500 octets or greater, to accommodate possible encapsulations (i.e., tunneling) without incurring IPv6-layer fragmentation.

From each link to which a node is directly attached, the node must be able to accept packets as large as that link's MTU.

It is strongly recommended that IPv6 nodes implement Path MTU Discovery [RFC-1981], in order to discover and take advantage of path MTUs greater than 1280 octets. However, a minimal IPv6 implementation (e.g., in a boot ROM) may simply restrict itself to sending packets no larger than 1280 octets, and omit implementation of Path MTU Discovery.

In order to send a packet larger than a path's MTU, a node may use the IPv6 Fragment header to fragment the packet at the source and have it reassembled at the destination(s). However, the use of such fragmentation is discouraged in any application that is able to adjust its packets to fit the measured path MTU (i.e., down to 1280 octets).

A node must be able to accept a fragmented packet that, after reassembly, is as large as 1500 octets. A node is permitted to accept fragmented packets that reassemble to more than 1500 octets. An upper-layer protocol or application that depends on IPv6 fragmentation to send packets larger than the MTU of a path should not send packets larger than 1500 octets unless it has assurance that the destination is capable of reassembling packets of that larger size.

In response to an IPv6 packet that is sent to an IPv4 destination (i.e., a packet that undergoes translation from IPv6 to IPv4), the originating IPv6 node may receive an ICMP Packet Too Big message reporting a Next-Hop MTU less than 1280. In that case, the IPv6 node is not required to reduce the size of subsequent packets to less than 1280, but must include a Fragment header in those packets so that the IPv6-to-IPv4 translating router can obtain a suitable Identification value to use in resulting IPv4 fragments. Note that this means the payload may have to be reduced to 1232 octets (1280 minus 40 for the IPv6 header and 8 for the Fragment header), and smaller still if additional extension headers are used.

6. Flow Labels

The 20-bit Flow Label field in the IPv6 header may be used by a source to label sequences of packets for which it requests special handling by the IPv6 routers, such as non-default quality of service or "real-time" service. This aspect of IPv6 is, at the time of writing, still experimental and subject to change as the requirements for flow support in the Internet become clearer. Hosts or routers that do not support the functions of the Flow Label field are required to set the field to zero when originating a packet, pass the field on unchanged when forwarding a packet, and ignore the field when receiving a packet.

Appendix A describes the current intended semantics and usage of the Flow Label field.

7. Traffic Classes

The 8-bit Traffic Class field in the IPv6 header is available for use by originating nodes and/or forwarding routers to identify and distinguish between different classes or priorities of IPv6 packets. At the point in time at which this specification is being written, there are a number of experiments underway in the use of the IPv4 Type of Service and/or Precedence bits to provide various forms of "differentiated service" for IP packets, other than through the use of explicit flow set-up. The Traffic Class field in the IPv6 header is intended to allow similar functionality to be supported in IPv6.

It is hoped that those experiments will eventually lead to agreement on what sorts of traffic classifications are most useful for IP packets. Detailed definitions of the syntax and semantics of all or

some of the IPv6 Traffic Class bits, whether experimental or intended for eventual standardization, are to be provided in separate documents.

The following general requirements apply to the Traffic Class field:

- o The service interface to the IPv6 service within a node must provide a means for an upper-layer protocol to supply the value of the Traffic Class bits in packets originated by that upper-layer protocol. The default value must be zero for all 8 bits.
- o Nodes that support a specific (experimental or eventual standard) use of some or all of the Traffic Class bits are permitted to change the value of those bits in packets that they originate, forward, or receive, as required for that specific use. Nodes should ignore and leave unchanged any bits of the Traffic Class field for which they do not support a specific use.
- o An upper-layer protocol must not assume that the value of the Traffic Class bits in a received packet are the same as the value sent by the packet's source.

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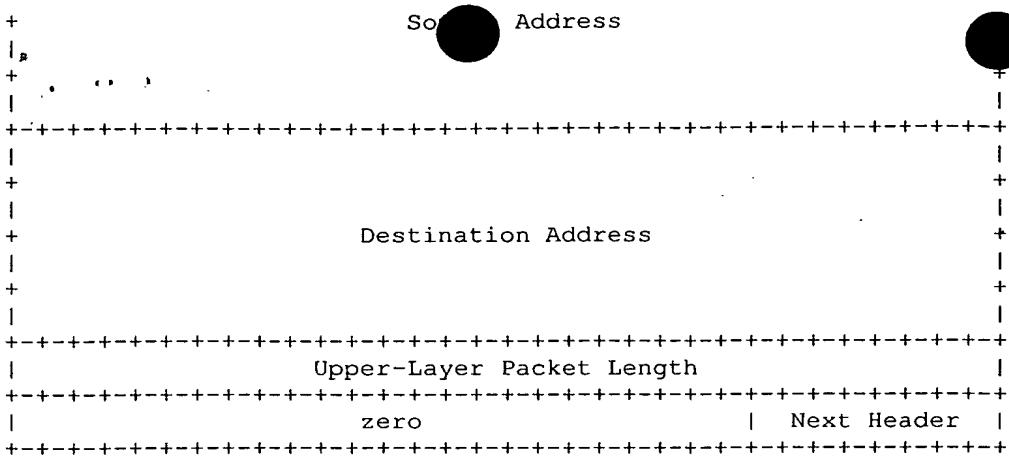
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8. Upper-Layer Protocol Issues

8.1 Upper-Layer Checksums

Any transport or other upper-layer protocol that includes the addresses from the IP header in its checksum computation must be modified for use over IPv6, to include the 128-bit IPv6 addresses instead of 32-bit IPv4 addresses. In particular, the following illustration shows the TCP and UDP "pseudo-header" for IPv6:



- o If the IPv6 packet contains a Routing header, the Destination Address used in the pseudo-header is that of the final destination. At the originating node, that address will be in the last element of the Routing header; at the recipient(s), that address will be in the Destination Address field of the IPv6 header.
- o The Next Header value in the pseudo-header identifies the upper-layer protocol (e.g., 6 for TCP, or 17 for UDP). It will differ from the Next Header value in the IPv6 header if there are extension headers between the IPv6 header and the upper-layer header.
- o The Upper-Layer Packet Length in the pseudo-header is the length of the upper-layer header and data (e.g., TCP header plus TCP data). Some upper-layer protocols carry their own

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length information (e.g., the Length field in the UDP header); for such protocols, that is the length used in the pseudo-header. Other protocols (such as TCP) do not carry their own length information, in which case the length used in the pseudo-header is the Payload Length from the IPv6 header, minus the length of any extension headers present between the IPv6 header and the upper-layer header.

- o Unlike IPv4, when UDP packets are originated by an IPv6 node, the UDP checksum is not optional. That is, whenever originating a UDP packet, an IPv6 node must compute a UDP checksum over the packet and the pseudo-header, and, if that computation yields a result of zero, it must be changed to hex FFFF for placement in the UDP header. IPv6 receivers must discard UDP packets containing a zero checksum, and should log the error.

The IPv6 version of ICMP [ICMPv6] includes the above pseudo-header in its checksum computation; this is a change from the IPv4 version of ICMP, which does not include a pseudo-header in its checksum. The reason for the change is to protect ICMP from misdelivery or corruption of those fields of the IPv6 header on which it depends, which, unlike IPv4, are not covered by an internet-layer checksum. The Next Header field in the pseudo-header for ICMP contains the value 58, which identifies the IPv6 version of ICMP.

8.2 Maximum Packet Lifetime

Unlike IPv4, IPv6 nodes are not required to enforce maximum packet lifetime. That is the reason the IPv4 "Time to Live" field was renamed "Hop Limit" in IPv6. In practice, very few, if any, IPv4 implementations conform to the requirement that they limit packet lifetime, so this is not a change in practice. Any upper-layer protocol that relies on the internet layer (whether IPv4 or IPv6) to limit packet lifetime ought to be upgraded to provide its own mechanisms for detecting and discarding obsolete packets.

8.3 Maximum Upper-Layer Payload Size

When computing the maximum payload size available for upper-layer data, an upper-layer protocol must take into account the larger size of the IPv6 header relative to the IPv4 header. For example, in IPv4, TCP's MSS option is computed as the maximum packet size (a default value or a value learned through Path MTU Discovery) minus 40 octets (20 octets for the minimum-length IPv4 header and 20 octets for the minimum-length TCP header). When using TCP over IPv6, the MSS must be computed as the maximum packet size minus 60 octets,

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because the minimum-length IPv6 header (i.e., an IPv6 header with no extension headers) is 20 octets longer than a minimum-length IPv4 header.

8.4 Responding to Packets Carrying Routing Headers

When an upper-layer protocol sends one or more packets in response to a received packet that included a Routing header, the response packet(s) must not include a Routing header that was automatically derived by "reversing" the received Routing header UNLESS the integrity and authenticity of the received Source Address and Routing header have been verified (e.g., via the use of an Authentication header in the received packet). In other words, only the following kinds of packets are permitted in response to a received packet bearing a Routing header:

- o Response packets that do not carry Routing headers.
- o Response packets that carry Routing headers that were NOT derived by reversing the Routing header of the received packet (for example, a Routing header supplied by local configuration).
- o Response packets that carry Routing headers that were derived by reversing the Routing header of the received packet IF AND ONLY IF the integrity and authenticity of the Source Address and Routing header from the received packet have been verified by the responder.

Appendix A. Semantics and Usage of the Flow Label Field

A flow is a sequence of packets sent from a particular source to a particular (unicast or multicast) destination for which the source desires special handling by the intervening routers. The nature of that special handling might be conveyed to the routers by a control protocol, such as a resource reservation protocol, or by information within the flow's packets themselves, e.g., in a hop-by-hop option. The details of such control protocols or options are beyond the scope of this document.

There may be multiple active flows from a source to a destination, as well as traffic that is not associated with any flow. A flow is uniquely identified by the combination of a source address and a non-zero flow label. Packets that do not belong to a flow carry a flow label of zero.

A flow label is assigned to a flow by the flow's source node. New flow labels must be chosen (pseudo-)randomly and uniformly from the range 1 to FFFF hex. The purpose of the random allocation is to make any set of bits within the Flow Label field suitable for use as a hash key by routers, for looking up the state associated with the flow.

All packets belonging to the same flow must be sent with the same source address, destination address, and flow label. If any of those packets includes a Hop-by-Hop Options header, then they all must be originated with the same Hop-by-Hop Options header contents (excluding the Next Header field of the Hop-by-Hop Options header). If any of those packets includes a Routing header, then they all must be originated with the same contents in all extension headers up to and including the Routing header (excluding the Next Header field in the Routing header). The routers or destinations are permitted, but not required, to verify that these conditions are satisfied. If a violation is detected, it should be reported to the source by an ICMP Parameter Problem message, Code 0, pointing to the high-order octet of the Flow Label field (i.e., offset 1 within the IPv6 packet).

The maximum lifetime of any flow-handling state established along a flow's path must be specified as part of the description of the state-establishment mechanism, e.g., the resource reservation protocol or the flow-setup hop-by-hop option. A source must not re-use a flow label for a new flow within the maximum lifetime of any flow-handling state that might have been established for the prior use of that flow label.

When a node stops and restarts (e.g., as a result of a "crash"), it must be careful not to use a flow label that it might have used for an earlier flow whose lifetime may not have expired yet. This may be accomplished by recording flow label usage on stable storage so that it can be remembered across crashes, or by refraining from using any flow labels until the maximum lifetime of any possible previously established flows has expired. If the minimum time for rebooting the node is known, that time can be deducted from the necessary waiting period before starting to allocate flow labels.

There is no requirement that all, or even most, packets belong to flows, i.e., carry non-zero flow labels. This observation is placed here to remind protocol designers and implementors not to assume otherwise. For example, it would be unwise to design a router whose performance would be adequate only if most packets belonged to flows, or to design a header compression scheme that only worked on packets that belonged to flows.

This appendix gives some advice on how to lay out the fields when designing new options to be placed in the Hop-by-Hop Options header or the Destination Options header, as described in section 4.2. These guidelines are based on the following assumptions:

- o One desirable feature is that any multi-octet fields within the Option Data area of an option be aligned on their natural boundaries, i.e., fields of width n octets should be placed at an integer multiple of n octets from the start of the Hop-by-Hop or Destination Options header, for $n = 1, 2, 4$, or 8 .
- o Another desirable feature is that the Hop-by-Hop or Destination Options header take up as little space as possible, subject to the requirement that the header be an integer multiple of 8 octets long.
- o It may be assumed that, when either of the option-bearing headers are present, they carry a very small number of options, usually only one.

These assumptions suggest the following approach to laying out the fields of an option: order the fields from smallest to largest, with no interior padding, then derive the alignment requirement for the entire option based on the alignment requirement of the largest field (up to a maximum alignment of 8 octets). This approach is illustrated in the following examples:

Example 1

If an option X required two data fields, one of length 8 octets and one of length 4 octets, it would be laid out as follows:

```
+-----+-----+-----+-----+-----+-----+-----+-----+
| Option Type=X | Opt Data Len=12 |
+-----+-----+-----+-----+-----+-----+-----+-----+
|           4-octet field           |
+-----+-----+-----+-----+-----+-----+-----+-----+
|           8-octet field           |
+-----+-----+-----+-----+-----+-----+-----+-----+
```

Its alignment requirement is $8n+2$, to ensure that the 8 -octet field starts at a multiple-of- 8 offset from the start of the enclosing header. A complete Hop-by-Hop or Destination Options header containing this one option would look as follows:

```
+-----+-----+-----+-----+-----+-----+-----+-----+
| Next Header | Hdr Ext Len=1 | Option Type=X | Opt Data Len=12 |
+-----+-----+-----+-----+-----+-----+-----+-----+
|           4-octet field           |
+-----+-----+-----+-----+-----+-----+-----+-----+
|           8-octet field           |
+-----+-----+-----+-----+-----+-----+-----+-----+
```

Example 2,

If an option Y required three data fields, one of length 4 octets, one of length 2 octets, and one of length 1 octet, it would be laid out as follows:

```
+-----+  
| Option Type=Y |  
+-----+  
|Opt Data Len=7 | 1-octet field | 2-octet field |  
+-----+  
| 4-octet field |  
+-----+
```

Its alignment requirement is $4n+3$, to ensure that the 4-octet field starts at a multiple-of-4 offset from the start of the enclosing header. A complete Hop-by-Hop or Destination Options header containing this one option would look as follows:

```
+-----+  
| Next Header | Hdr Ext Len=1 | Pad1 Option=0 | Option Type=Y |  
+-----+  
|Opt Data Len=7 | 1-octet field | 2-octet field |  
+-----+  
| 4-octet field |  
+-----+  
| PadN Option=1 |Opt Data Len=2 | 0 | 0 |  
+-----+
```

Example 3

A Hop-by-Hop or Destination Options header containing both options X and Y from Examples 1 and 2 would have one of the two following formats, depending on which option appeared first:

```
+-----+  
| Next Header | Hdr Ext Len=3 | Option Type=X |Opt Data Len=12|  
+-----+  
| 4-octet field |  
+-----+  
| 8-octet field |  
+-----+  
| PadN Option=1 |Opt Data Len=1 | 0 | Option Type=Y |  
+-----+  
|Opt Data Len=7 | 1-octet field | 2-octet field |  
+-----+  
| 4-octet field |  
+-----+  
| PadN Option=1 |Opt Data Len=2 | 0 | 0 |  
+-----+
```

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Security Considerations

The security features of IPv6 are described in the Security Architecture for the Internet Protocol [RFC-2401].

Acknowledgments

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CHANGES SINCE RFC-1883

This memo has the following changes from RFC-1883. Numbers identify the Internet-Draft version in which the change was made.

- 02) Removed all references to jumbograms and the Jumbo Payload option (moved to a separate document).
- 02) Moved most of Flow Label description from section 6 to (new) Appendix A.
- 02) In Flow Label description, now in Appendix A, corrected maximum Flow Label value from FFFFFF to FFFF (i.e., one less "F") due to reduction of size of Flow Label field from 24 bits to 20 bits.
- 02) Renumbered (relettered?) the previous Appendix A to be Appendix B.
- 02) Changed the wording of the Security Considerations section to avoid dependency loop between this spec and the IPsec specs.
- 02) Updated R. Hinden's email address and company affiliation.

- 01) In section 3, changed field name "Class" to "Traffic Class" and increased its size from 4 to 8 bits. Decreased size of Flow Label field from 24 to 20 bits to compensate for increase in

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- 01) In section 4.1, restored the order of the Authentication Header and the ESP header, which were mistakenly swapped in the 00 version of this memo.
- 01) In section 4.4, deleted the Strict/Loose Bit Map field and the strict routing functionality from the Type 0 Routing header, and removed the restriction on number of addresses that may be carried in the Type 0 Routing header (was limited to 23 addresses, because of the size of the strict/loose bit map).
- 01) In section 5, changed the minimum IPv6 MTU from 576 to 1280 octets, and added a recommendation that links with configurable MTU (e.g., PPP links) be configured to have an MTU of at least 1500 octets.
- 01) In section 5, deleted the requirement that a node must not send fragmented packets that reassemble to more than 1500 octets without knowledge of the destination reassembly buffer size, and replaced it with a recommendation that upper-layer protocols or applications should not do that.
- 01) Replaced reference to the IPv4 Path MTU Discovery spec (RFC-1191) with reference to the IPv6 Path MTU Discovery spec (RFC-1981), and deleted the Notes at the end of section 5 regarding Path MTU Discovery, since those details are now covered by RFC-1981.
- 01) In section 6, deleted specification of "opportunistic" flow set-up, and removed all references to the 6-second maximum lifetime for opportunistically established flow state.
- 01) In section 7, deleted the provisional description of the internal structure and semantics of the Traffic Class field, and specified that such descriptions be provided in separate documents.

- 00) In section 4, corrected the Code value to indicate "unrecognized Next Header type encountered" in an ICMP Parameter Problem message (changed from 2 to 1).
- 00) In the description of the Payload Length field in section 3, and of the Jumbo Payload Length field in section 4.3, made it clearer that extension headers are included in the payload length count.

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- 00) In section 4.1, swapped the order of the Authentication header

and the ESP header. (Note: this was a mistake, and the change was undone in version 01.)

- 00) In section 4.2, made it clearer that options are identified by the full 8-bit Option Type, not by the low-order 5 bits of an Option Type. Also specified that the same Option Type numbering space is used for both Hop-by-Hop Options and Destination Options headers.
- 00) In section 4.4, added a sentence requiring that nodes processing a Routing header must send an ICMP Packet Too Big message in response to a packet that is too big to fit in the next hop link (rather than, say, performing fragmentation).
- 00) Changed the name of the IPv6 Priority field to "Class", and replaced the previous description of Priority in section 7 with a description of the Class field. Also, excluded this field from the set of fields that must remain the same for all packets in the same flow, as specified in section 6.
- 00) In the pseudo-header in section 8.1, changed the name of the "Payload Length" field to "Upper-Layer Packet Length". Also clarified that, in the case of protocols that carry their own length info (like non-jumbogram UDP), it is the upper-layer-derived length, not the IP-layer-derived length, that is used in the pseudo-header.
- 00) Added section 8.4, specifying that upper-layer protocols, when responding to a received packet that carried a Routing header, must not include the reverse of the Routing header in the response packet(s) unless the received Routing header was authenticated.
- 00) Fixed some typos and grammatical errors.
- 00) Authors' contact info updated.

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